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SOLAR MICROWAVE MILLISECOND SPIKE AT 2.84 GHZ

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ABSTRACT

Using the high time resolution of 1 ms, the data of solar microwave millisecond spike (MMS) event more than two hundred times at the frequency of 2.84 GHz have been recorded at Beijing (Peking) Observatory since May 1981. The present paper has made a preliminary analysis. It can be seen from these data that the MMS-events have a variety of the fast activities such as the dispersed and isolated spikes, the clusters of the crowded spikes, the weak spikes superimposed on the noise background, and the phenomena of absorption. The marked differences from that observed with lower time resolution are presented. Using these data, a valuable statistical analysis has been made. There are close correlation between MMS-events and hard X-ray bursts, and fast drifting radio bursts. The MMS-events are highly dependent with the type of active regions and the magnetic field configuration. It seems to be crucial to find out the accurate positions on the active region where the MMS-events happen and to make co-operative observations at different band during the special period when specific active regions appear on solar disk.

I. INTRODUCTION

At Beijing Observatory, a fast sampling recorder with time constant of 1 ms for solar observation at 2.84 GHz was devised in 1981 (Jin, Zhao and Fu). From April 1981 to June 1983, these systems worked in 480 days, about 250 events have been recorded. These results have given us a clue to the researching on the physical process of microwave millisecond spike (MMS) emission linked with its associated phenomena.

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II. ANALYSIS OF FEATURES OF THE MMS-EVENTS

There are many and varied structures of the spikes in the MMS-events. They may be classified as follows:

1) Dispersed or isolated spike clusters:

Among all MMS-events recorded spike bursts grouped in isolated clusters occur most frequently. The duration of the clusters is often 10-100 ms and the time interval between clusters is about 100-1000 ms. Each single spike generally last about 3-10 ms, sometimes longer, with peak flux density higher than 2000 sfu., sometimes higher than 1000 sfu.

Generally, the isolated spike clusters correspond with subflares and/or impulsive radio bursts (type 3s, 5s and 8s). Fig. 1 shows the record of MMS-event occurring at 0544 UT on Feb. 3, 1982. The duration of the largest spike is 19 ms, with the amplitude of 2.2×10^4 sfu. Most MMS-events contained isolated spike clusters, while about 1/3 of the events were completely composed of isolated spike clusters.

2) Crowded spike clusters

Such clusters are composed of a number of crowded spike pulses. Duration of each cluster amounts to tens to hundreds of ms, even more than 10 s. Individual spike in the cluster has short duration (not more than a few ms) and high flux density (about ten thousands sfu.). About half of

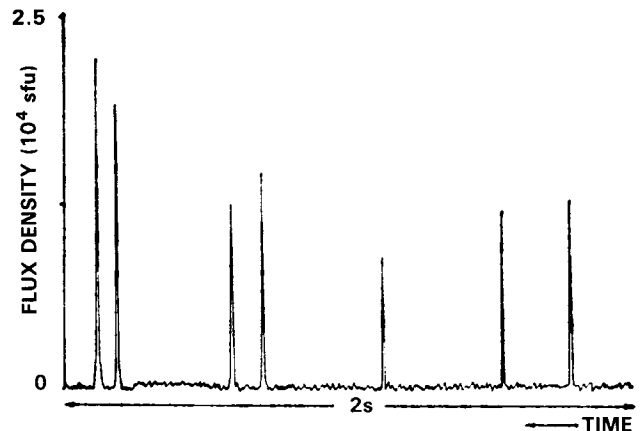


Fig. 1 Isolated spike cluster occurring at 0544 UT, on Feb. 3, 1982

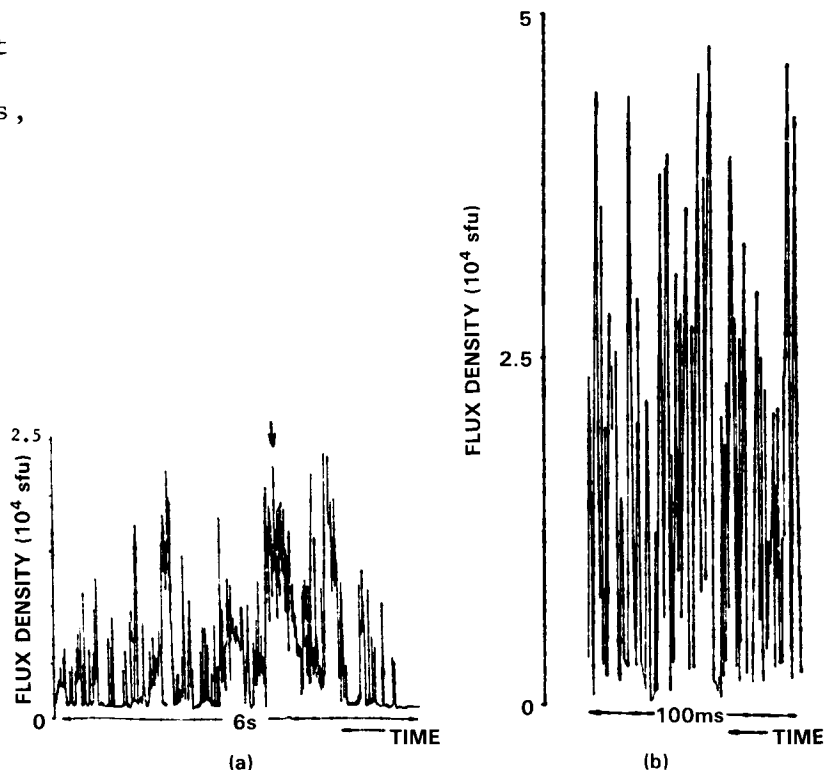


Fig. 2 a) A part of the crowded spike cluster occurring at 0839 UT. on May 16, 1981.

b) The details indicated by an arrow in Fig 2a.

the MMS-event recorded contained crowded spike clusters. About 10 events of such clusters occurred without other types of clusters during the period mentioned above. Fig. 2 indicates a part of the crowd spike clusters contained in the May 16, 1981 event. It is the biggest event among the whole record we obtained. There were 37 spikes in the 100 ms time interval. The average duration of individual spike is 2-3 ms. Some of them has a duration of less than 1 ms, the time resolution of the radio telescope. The amplitude of the largest spikes in the time interval is 4.8×10^4 sfu., with the duration of less than 4 ms. The most crowded cluster recorded had 430 spike each minute.

3) Long lasting weak spike clusters

They display as some small spike on the noise background. The spikes sometimes are isolated, sometimes crowded in groups. Their flux density is generally of the order of 1000 sfu. The clusters have a duration of several minutes to tens minutes, even a couple of hours. They look like a "noise storm" at microwave band. Generally, the long-lasting weak spike clusters correspond to weak radio burst or flares. About a half of all MMS-events recorded belong to this type, which generally happens when some specific active region appears. Fig. 3 shows the long-lasting weak spike cluster recorded on July 15, 1981.

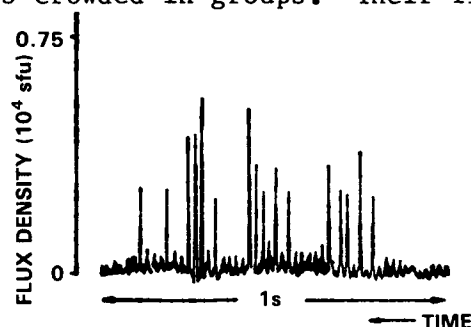


Fig. 3 Weak spike cluster in the noise background occurring at 0910 UT. on July 15, 1981.

4) Absorption phenomena

Besides the upward spike pulses, we have recorded a number of downward negative ones, namely absorption phenomena. Their flux density is obviously lower than that of slow burst level. Of all the MMS events analyzed about 10 events contained such absorption phenomena. Fig. 4, Fig. 5 shows a part of the MMS recorded at 0901 UT. on July 30, 1981 and at 0403 UT on July 21, 1981, respectively. It can be seen that there are at least two kinds of absorption phenomena in the MMS-events.

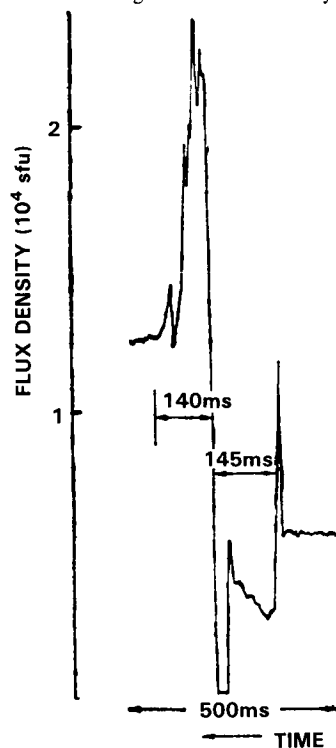


Fig.4 Absorption phenomenon occurring at 0901 UT. on July 30, 1981

Figs. 6, 7, 8, and 9 show four typical MMS-events recorded on May 16, 1981 (Zhao, R., and Jin, S. 1982), July 31, 1981 (Fu, Q. and et al. 1982) Feb. 3, 1982 and Mar. 30, 1982.

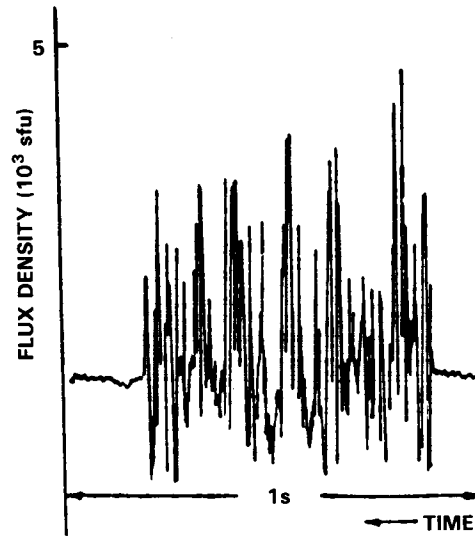


Fig. 5 Absorption phenomenon occurring at 0403 UT. on July 21, 1981.

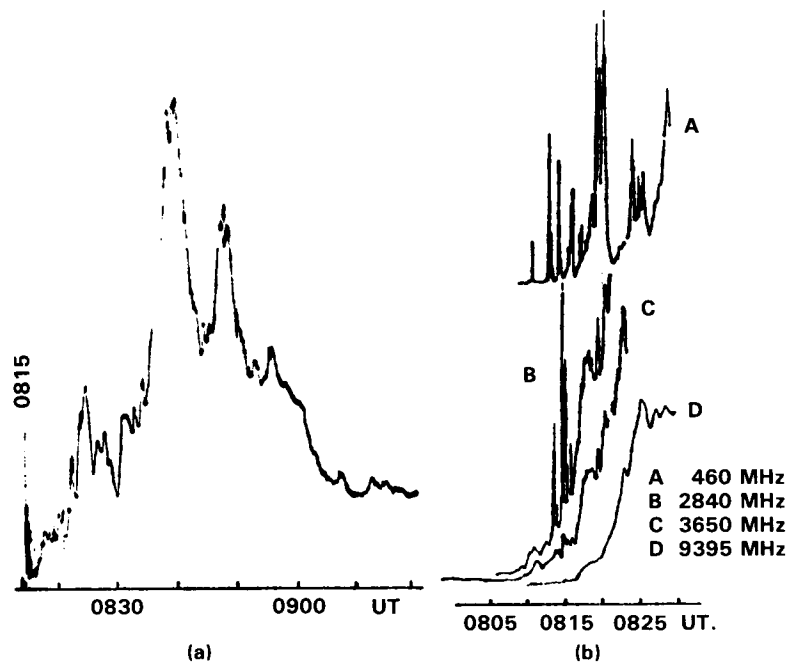


Fig. 6 Microwave outburst associated MMS-event (Figures 2, 10) occurred on May 16, 1981
 a) slow record at 2.84 GHz
 b) impulsive structures during initial rising phase at 460, 2840, 3650, and 9395 MHz

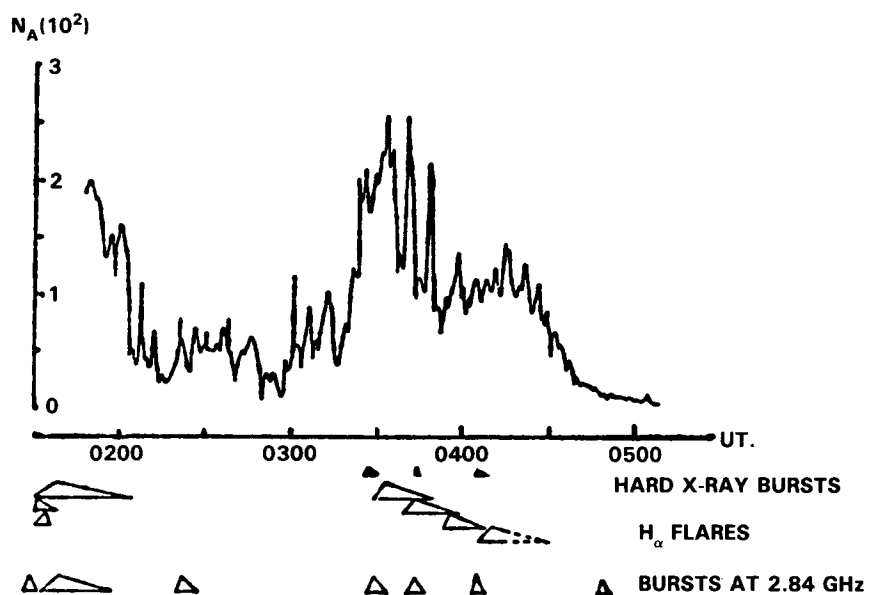


Fig. 7 Spike's number per minute (N_A) and X-ray bursts, flares, and radio bursts at 2.84 GHz associated on the event of July 31, 1981.

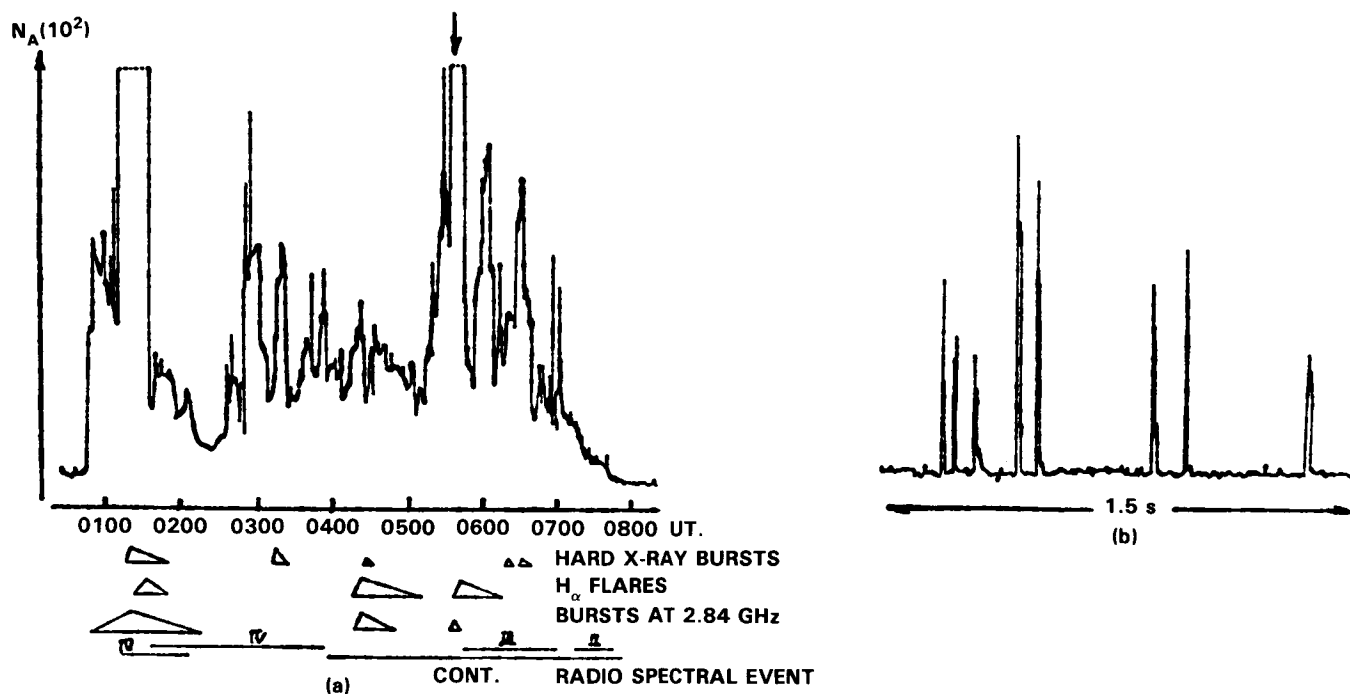


Fig. 8 The event of Feb 2, 1982.

- spike's number per minute (N_A) and other solar activities associated.
- the details of flux density at the time indicated by an arrow in Fig. 8a.

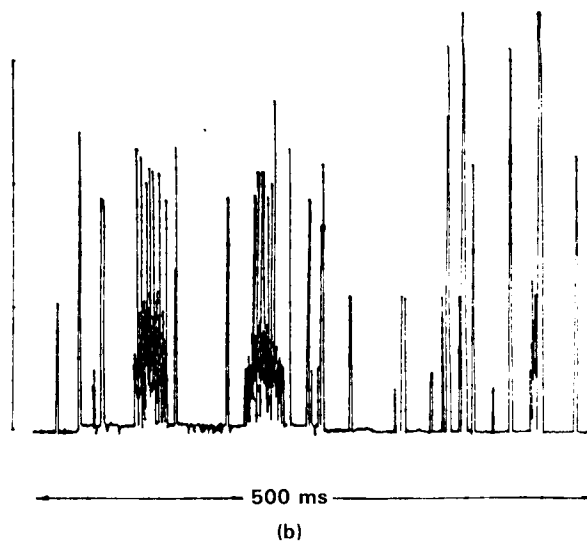
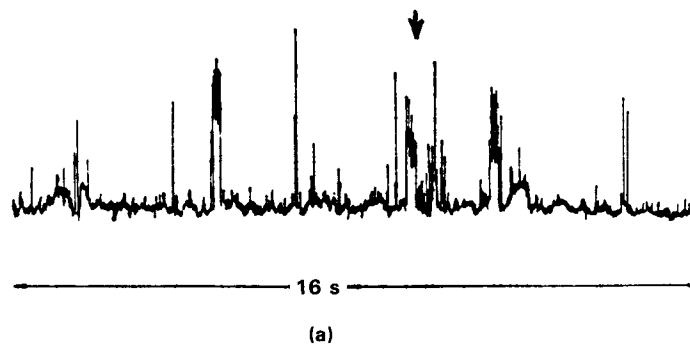


Fig. 9 The event of Mar. 30, 1982
a) a part of record of 16 seconds
b) the details indicated by an arrow in a).

III. CHARACTERS OF OUR OBSERVATIONS

Owing to the time resolution obtained by us is higher than those obtained by Slottje, C. (1980) and Drago, F. (1977), the morphology of events observed by us is markedly different from that by them and reflect MMS emission more accurately. It has been found that:

- 1) The amplitude of the largest spike is more than 5×10^4 sfu. (possibly larger than 10^5 sfu.).
- 2) The duration of most spikes in great events is less than 4 ms. Some are less than 1 ms (Fig. 1).
- 3) The ratio of the amplitude of individual spike to the slow burst background in the event of May 16, 1981 is 100 to 500.
- 4) Some spikes which cannot be resolved with lower time resolution have been resolved. Fig. 10a show a recorded group of spikes. Fig. 10b shows the same groups of spikes with a time constant of 10 ms. It can be clearly seen that the group of spikes has become a noise pattern with random fluctuations. The amplitude has decreased to less than one half of the original pattern, while the continuous background has increased greatly.
- 5) Because of the many records with high temporal resolution, it seems likely that the basic unit of MMS structure is a spike having a duration from less than 1 ms to tens or hundreds of ms. Spikes appear individually to form a sparse cluster as a "noise storm" (Fig. 3), or in groups with a group duration of tens or hundreds of ms and even tens of seconds. There are a number of groups in an event. With a lack of temporal resolution, these groups become noise pattern with random fluctuation. Some "switch-on and switch off structures" (Slottje, C. 1980) recorded with a lower time resolution

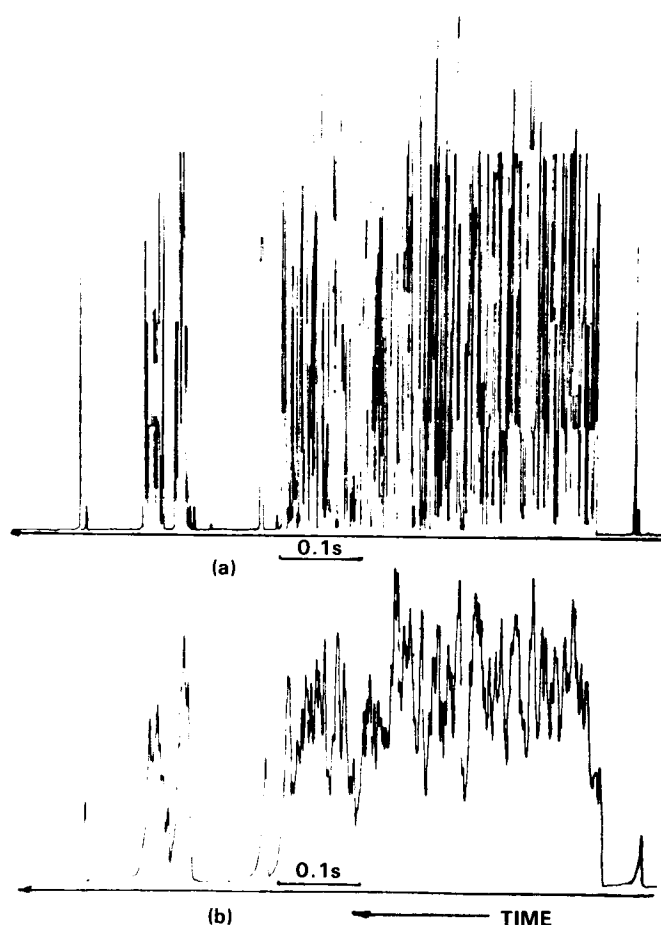


Fig. 10 A part of spikes occurring at 0815 UT. on May 16, 1981
a) with time constant of 1 ms
b) with time constant of 10 ms

are possibly an assembly of a large number of unresolved spikes. The first spike marks the beginning of the assembly, and the last spike the end. Its rising time or falling time amounts to only 1 ~ 2 ms (Fig. 10).

6) Owing to continuous patrolling and maintaining a record of N_A , spike's number each minute, a valuable statistical analysis was made with using the events recorded.

IV. CORRELATION BETWEEN MMS-EVENTS AND OTHER SOLAR ACTIVITIES:

1) The correlation between MMS event at 10 cm and solar activity period:

Table 1 and Fig. 11 show the number of MMS-events recorded at different periods of solar activity. It indicates that the appearance of MMS-events decreases as solar activity decends.

Table 1

	May-Dec. 1981	Jan.-Mar. 1982	Mar.-Sept. 1982	Jan.-June 1983
No. of MMS events/100 ^h	11.2	10.8	4.6	2.3

2) From Oct. 1981 to July 1982, the MMS-events were recorded in 142 days, in these days, 299 hard x-ray bursts recorded ("NASA Technical Memorandum 84998", and "Listing of x-ray flares on HINOTORI"). 94 of them are found to be co-occurrence with the MMS events. This amounts to a percentage of 31.4%, which is much higher than those for the radio bursts and optical flares with only 17.5% and 8.6% respectively are associated MMS-events. If taken the "satellite nights" into consideration, the significance of x-ray burst and MMS-event association may even be enhanced.

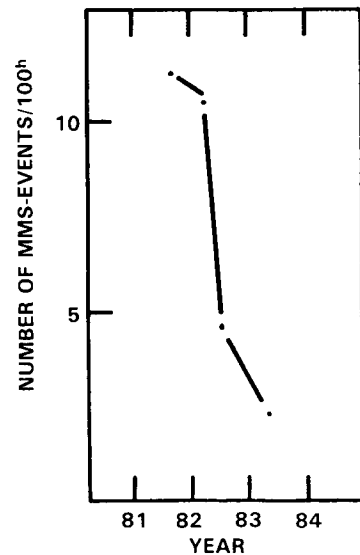


Fig. 11 The correlation between MMS-event at 10 cm and solar activity period

3) Table 2 gives the statistics of the percentage of MMS events that were associated with the radio bursts, optical flares, hard x-ray burst and radio spectral events. It should be pointed out that the most of radio burst associated with MMS events contain impulsive structure (Fig. 6). Some of the impulsive structure has been proved that they are integrated with a great number of spikes (Fu, Q., Li, C., and Jin, S. 1985), and the most of radio spectral events associated with MMS-events are type III.

Table 2

	radio bursts	optical flare	hard x-ray bursts	radio spectral events
MMS-events	82%	59%	34.6%	61.5%
Peaks* in MMS-events	64%	59.6%	49.2%	

*The amount of peaks in the plot of spike's number per minute via time.

4) Relation between MMS-events and solar active regions:

For those MMS-events associated with solar flares, we can relate former with the active regions where the flares located. 149 such cases have been found for statistical study. Results are listed in Table 3.

We notice that 87.3% of such MMS events occurred in the regions with magnetic field more than 2000 Gauss, while in δ and $\beta\gamma$ magnetic configurations, which are rather rare as a whole, concentrated 54.6% of the MMS-events generation. When referring to sunspot group, we find that 84.8% of the events are associated with type D, E and F. These lead to the conclusion that strong and complex magnetic field is an important indicator for the happening of MMS-events.

Table 3

Relation Between MMS-Events and Solar Active Regions

Type of Magnetic Structure	Percentage of MMS-events associated	Magnetic field strength (Gauss)	Percentage of MMS-events associated	Type of Sunspot group	Percentage of MMS-events associated
α	4.2	> 2000	87.3	E	34.8
β	41.2	> 2500	62.0	F	24.6
$\beta\gamma$	17.5			D	25.4
δ	37.1			other	15.2

5) The closeness of association between the MMS-events and hard x-ray bursts differs significantly at different periods. The period Oct. 8-24, 1981 is a noticeable example. During this period 24 MMS-events (with 28 peaks) and 62 hard x-ray events were registered when the time intervals of our radiometer's working. 93% of the peaks of events has x-ray association and for all the x-ray events, 41% are co-occurrence with MMS-events. These correlations are much higher than the average values over all periods (49.2% and 31.4% respectively as stated before). Almost

whole of them were located on active regions 17906 and 17923. This means that for some particular solar active regions, the probability of co-occurrence of MMS-events and x-ray events can be very high.

6) The longitude distribution of the flares associated with MMS-events: Fig. 12 and Fig. 13 show the distribution of these flares in longitude of solar disk and in Carrington longitude, respectively. As one may expect, there is obvious directivity of the emission of these events. The "half-power" beamwidth of emission is estimated to be 45° to 50° . The distribution is somewhat asymmetric, in favor of the west part of the disk. There are some active longitude (as 300°) on solar disk for the flares associated with MMS-events as the normal flares, from the Fig. 13. It means that, similarly to normal flares, MMS-flares correlate to certain active places with long living on the solar disk.

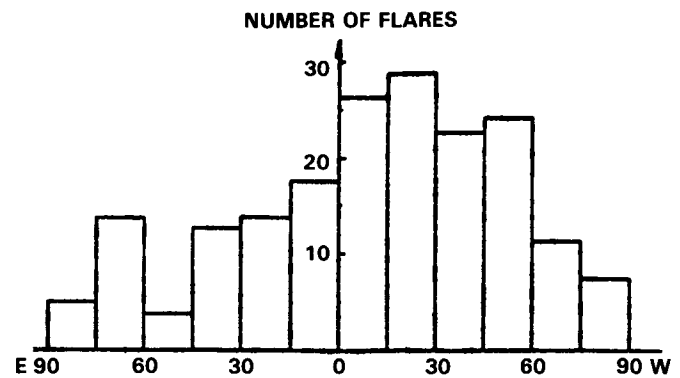


Fig. 12 The distribution of the flares associated with MMS-events in longitude of solar disk

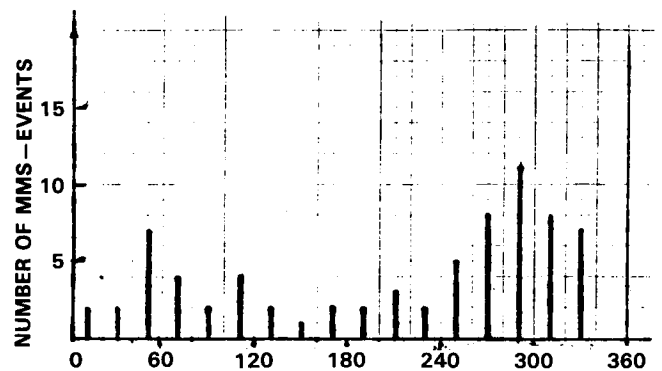


Fig. 13 The distribution of the flares associated with MMS-events in Carrington longitude

V. DISCUSSION:

Owing to the systematic observation with equipment of high time resolution (1 ms), some interesting new features of fast fine structure of solar microwave bursts have been revealed. For example, the MMS emission has shorter duration and higher flux density than were previously known, and the basic units of such fast activities are single spike crowded together forming separate clusters. Observation shows that many spikes are not yet resolved. Therefore, it is of importance to have the time resolution further improved.

With the observational data accumulated so far, the following results are worth noticing: the MMS events are closely correlated with hard x-ray bursts and with fast drifting dm bursts. Some MMS-events found no correspondence with the bursts at the same frequency on slow speed record but corresponded to the bursts occurring in other wavelengths. It is likely that the contribution of the spike clusters

were smoothed out on the slow speed record, it seems that they originate from different physical processes. Thus, such fast activity may be a fundamental process different from the flares and normal radio bursts. The MMS events are highly dependent with the type of active regions and the magnetic configuration of the active regions. Possibly, it is crucial to find out the accurate positions on the active region where the MMS-events happen and the position relative to the places where other solar activities associated occur, for judging what is better mechanism for MMS emission.

Since the discovery of solar microwave spike emission with high time resolution observations at cm wavelengths, much theoretical work on the interpretation of its high brightness temperature and polarized characteristics has been proposed. The mechanisms for generating MMS emission have been reviewed in more detail by the authors (Holma, G.D., 1982; Melrose, D.B., and Dulk, G.A., 1982). There is another type of cyclotron maser instability with a "hollow beam" distribution of electrons (Li, H., Li, C., and Fu, Q., 1985) seems to be more important than that associated with a loss-cone distribution. Possibly, different kinds of MMS emission have different mechanisms. It is important to make co-operative observations at different radio wavelengths, optical wavelengths, x-ray and others during the special period when specific, as mentioned in section IV, active region appear on solar disk for clarifying the essence of the fast fine structure emission.

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